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by

Z. Rychlicki, L. Jarzebinski



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FIRST LINE OF TEXT

The Problem of Automatizing Engineering Work

FIRST LINE OF TITLE

Zygmunt Rychlicki, engineer

Lech Jarzebiński, M.A., engineer

In recent years there has been explosive development of electronic data processing systems. With increasing frequency engineering and technical personnel at many centers are turning to automatic means of performing repetitive work. Today's digital computers possess ever-larger working storage, while at the same time there has been great progress in miniaturization. Execution speed of operations has increased a number of times. Meanwhile, peripheral devices have been developed which make possible input of data and output of results in digital or graphic form. The introduction of autocodes which permit the writing of technical problems with the aid of problem-oriented languages has enabled the majority of workers to use the computer without the necessity of laborious programming in the computer's internal language. Clear writing of problems which is close to the mathematical notation used by engineers is easy to check out and can be implemented by a relatively small number of programmers working on a problem. In design activities

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the development of the optimal design method became possible only after the introduction of electronic computer technology, with the growth of storage capacity and of execution speed having decisive significance. Because of high labor-intensiveness, design computations in the past could be performed by a simplified method and were limited to checking the projected design. The many repetitions of computations necessary for optimization were inconceivable using the slide rule or even the mechanical calculator. Computational models of that time, in spite of simplification, departed considerably from the actual design.

The introduction of high-speed digital computers led to development of a method of engineering analysis based on iterative computation. Computational solution became possible for problems on which mathematical analysis formerly had been performed only in a general sense. A typical example is analysis of air flow around composite aircraft structures during flight. Performing a large number of experiments on models during wind-tunnel tests is costly. Using the method of finite elements has made it possible to obtain results which coincide with experimental results. This method is even more successful in strength analyses, because it is based on representation of actual structures with the aid of a large number of simple elements. In the design process the designer must solve problems relating to construction, technology, and standards and materials. The latter are especially troublesome. Sorting through standards and descriptions of technological processes is rather tedious and quickly discourages most designers (even very conscientious ones). The development of systems for storing and filing this

information in computer memory has permitted fast sequential selection of descriptions needed at a given moment. A typical example is patent analysis, where, without the availability of a computer system, it is impractical to compare closely related patents with respect to their integrity. A qualitatively new tool has appeared with the creation of systems for direct interaction between designer and computer by means of the light pen, with which it is possible to draw on the screen of a reading unit.

Inquiries entered with a light pen or with a keyboard are transferred to the computer and processed, and the results of the analysis are transferred directly to a display. This process takes place in an extremely short time; the designer can formulate conclusions and make a decision. Optimal designing of aircraft structures requires dealing not only with technological and economic problems, but above all with aerodynamic and structural analysis. The use of graphoscopes permits high-speed analysis. Programs dealing with aerodynamics and structural analysis are worked out in advance and coded in computer storage. The designer can directly create an image of a structure on a screen in the form of a computational model and can apply external loads. After processing, the results are displayed in the form of a series of internal loads.

In subsequent approximations the image of the structure can be adjusted, for example, to optimize for minimum internal stresses and maximum lightness. A very important problem is that of representing shapes. The smoothness of shapes in the combination of various geometric forms is important. A valuable factor from the technological standpoint is the possibility of attaining the maximum

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developable surface.

In the process of conversing with the computer, the designer makes projection drawings. After processing he obtains three-dimensional images and can also call for correction of shapes at the angle achieving the necessary smoothness.

Computer Components and Structure

Electronic digital computers can perform certain simple operations on the numbers put into them, such as addition, subtraction, multiplication, transfer from one part of the computer to another, collection of data (presented in the form of series of suitably written symbols) from input devices, moving of data to output devices in the form of numbers, text, drawings, or series of suitably coded symbols, comparison of numbers, etc. The computer is also capable of performing simple monitoring operations for accuracy checks and precise control of a computation process. Basic components of a computer are: storage, the central processing unit, selector and multiplexor channels, and input/output devices connected to the channels by special control equipment. Fig. 1 shows the basic organization of a system. Computer storage is divided into working storage and auxiliary storage. A digital computer as a whole can be regarded as a device which receives data and instructions through an input unit, stores them in one or several forms depending on the system of storage being used, performs computations with an arithmetic unit, and delivers the results to an output unit, all under the direction of a control unit. The latest types of computers have a modular construction which allows them to be assembled from individual units in various configurations. Adding modules as

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needed, we can build either a minimal aggregation containing a central unit, a working storage block, and the simplest group of I/O devices, or a large computer with many modules of working storage and auxiliary storage, and a complex of machines working together with it - satellites and enlarged I/O equipment with high speeds and capacities. The choice of groupings depends only on the needs of the user.

The Arystomat 8320 automatic drafting desk is widely used in engineering. This machine draws at 30 m/min, with accuracy of ± 0.05 mm. Because of its large work surface (1200 x 1500 mm), the Arystomat 8320 has wide use in design offices. (Fig. 3)

The maximum drawing speed of the Arystomat 8330 is 12 m/min, and accuracy is up to 0.01 mm.

Programming

The proper operation of a computer is influenced by many factors, such as the complexity of the subject, degree of difficulty, and the skills of the workers who are to deal with the problem in the area of programming, in utilization of the computer, and in preparation of the subject for computation or design. Practice has shown that the development of design techniques of computation systems is influenced above all by the following factors:

- accurate formulation of the problem,
- method of solution,
- determination of the path of computations,
- development of a specific computation algorithm in the form of a chart or similar document,

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- writing of the program,
- implementation of the program,
- execution of computations.

Engineering problems to be solved on the digital computer are usually formulated by engineers who are not always familiar with the difficulties of programming. This is related to the difficulties in selecting the optimum method for solving a problem, which would permit solution in the simplest way possible, but with provision for all conditions and constraints given in the problem, and would permit in particular the required exactness of the results.

Efficient solution of a problem depends on:

- setting out quantitatively well-defined main goals for each item to be operated on,
- unequivocal definition of all additional requirements and constraints on the operation which hamper freedom of action,
- formulation of a synthetic criterion for assessing the attainment of a goal as a function of proximity to it, as well as the importance of meeting all additional requirements and constraints.

For this reason, in the course of working out a program we produce block diagrams which graphically show the sequences and modes of operations in the computation of a problem. Block diagrams of systems - whether general or more detailed - are nothing more than the representation in a graphical scheme of the sequence and interconnection of all the stages in the course of machine operation. The basic problem of block diagrams is to establish the proper sequence of machine operation. It should be emphasized here that the

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computer executes a program according to the sequence of instructions written by the programmer, while a block diagram serves the programmer in checking the writing of a program. The diagrams are rendered with standard graphical symbols, whose interconnection and interdependence are shown by lines linking the symbols. The lines have arrows indicating the sequence of processing. When designing a block diagram it is good practice to make a list of assumptions and to define the logical sequence of processing.

Use of Computers

We can distinguish three broad directions in the use of computers: the first is production and economic computing. In this category one can single out:

- automatic data processing systems involved with planning and record-keeping,
- methods of mathematical programming involved with optimizing a production program,
- management information systems (SIK [systemy informowania kierownictwa]), which generate information addressed to interested managers,
- automatic retrieval systems for scientific and technical information.

The second direction is design engineering computations as well as simulation methods.

The third direction is control; here we can distinguish:

- single-station operation (e.g. numerical machine tool control),
- production line control,

- processing center control,
- control of material flows,
- technological process control.

Although these directions in computer use have undergone parallel development, it is possible, depending on one's needs, to select those which are in the user's field of interest.

Among the more up-to-date directions in computer use are three-dimensional design computations using the finite elements method. An example of the application of this method involves the section of the C 135 airplane fuselage with a radar antenna housing. Pressures along the upper part of the fuselage are manifested in the aircraft's plane of symmetry, while pressures along the maximum curves of width are manifested on the sides of the fuselage. The data come from a free-stream test at mach 0.4, but the computed distributions are for an incompressible flow. On the basis of Goethert's law it may be concluded that correction for compressibility at $M = 0.4$ is negligible. Using the simulation method, it is possible to construct a mathematical description of an aircraft fuselage and to study the behavior of such a model in specified aerodynamic conditions without having to build a real model. To this end the designer supplies data on the object using external equipment. On the basis of the data, and utilizing special software, the computer performs computations and puts out the results. If the results are not satisfactory, the designer can supply new parameters modifying the description of the fuselage shape. The computation process is repeated. This procedure can be repeated until the fuselage satisfies the requirements. By means

of the graphical dialogue with the computer, the designer is able to use algebraic as well as geometric aspects in seeking a solution to a problem. A classic example of this is the designing of the path of feed for the cutting tool of a numerically controlled lathe. The designer draws the workpiece on a monitor screen with a light pen and program function keyboard. The computer turns out the corresponding data on paper tape, which then controls the operation of the lathe. The program carrier is punched tape 1. Information read out by a reader 2 is converted in a converter 3 to physical quantities (e.g. voltage, pulses of current, etc.), which are then directed to an interpolator 4 (information on displacement quantities of the machine table in the directions of coordinates X,Y) and to a unit 10 controlling auxiliary operations which are to be performed during the machining cycle. The interpolator simultaneously transmits signals for displacements in the direction of axes X and Y. In a collating unit 5, signals X_m are subtracted from signals X; signals X come to the collator from the interpolator and represent the assigned value of coordinate X; signals X_m (properly converted in converter 9) come from a sensor 8, which measures the actual position (or displacement) of the machine table in the direction of axis X. The difference in the signals $e=X-X_m$ controls the motor 7 so that e is reduced to zero. An identical system controls the cross slide in the direction of the other coordinate Y. We can also develop machining technology, i.e., technological documentation, using the computer, which means that files of operation sheets can also be developed on the computer. However, development of this problem in computer program

form is not an easy task. This task ought to be in the plans for research work in our industry. The examples chosen indicate the unusual possibilities of the computer.

It should be emphasized that, with intelligent utilization of technology in the field of design, and through judicious use of existing problem-oriented programs, computers can make the same breakthrough in the automatization of engineering activities as they made in the area of management. In the aircraft and propulsion industry, work is being carried out in the following areas:

- engineering design and strength computations,
- use of graphical means for representing computation results and for semiautomatic design work,
- implementation of a library of mathematical procedures directed by engineers which contains 48 separate programs in the RIAD computer series.

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